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DoE letter, 7/3/78; State Dept. ltr, 10/23/78
By JK NARS, Date 11/17/78

U. S. Atomic Energy Commission

NUCLEAR CRATERING EXPERIMENTS AND THE TEST BAN TREATY

Statement for November 18, 1965 Meeting
of the Atlantic-Pacific Interoceanic
Canal Study Commission

I. Introduction

From our discussions in July, you are aware of some of the more important technical factors involved in nuclear excavation, the general status of the technology, and the need for our experimental program. You are also aware, in general, of the relation of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, Outer Space and Under Water to the experimental program, of the procedures used within Government to consider cratering experiments, and of some of the political and technical factors involved in this review. From your tour of the Nevada Test Site in October and your briefings by the Lawrence Radiation Laboratory, you are aware in some detail of the technical information which needs to be obtained before a determination of the feasibility of using nuclear explosives to excavate a sea-level canal can be made. At your request, I would now like to discuss with you specifically and in more detail the technical and political questions involved in approving the specific cratering experiments needed for your determinations on feasibility and costs.

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II. Proposed Program of Experiments

A. Cabriolet

Project Cabriolet is proposed as the next experiment in our nuclear excavation program. The AEC has just completed its preliminary analysis of this experiment and is beginning discussions within the Administration in order to obtain the preliminary approval needed for beginning construction for the experiment. This experiment involves the detonation of a nominal 2 kiloton explosive at optimum cratering depth in hard rock at our Nevada Test Site. The primary objective of the experiment is to confirm the low levels of radioactivity which we expect to escape in cratering experiments [redacted] the down-hole debris entrapment technique. With the improvements in the explosive, we expect the levels of radioactivity from Cabriolet at national boundaries to be low enough not to create undue political problems. With correction of the stemming difficulties involved in the Palanquin experiment, we expect the levels ? after 50 hours to be only slightly above the levels that were actually at the borders of the U. S. in Palanquin. If the down-hole debris entrapment technique works, the levels of radioactivity from Cabriolet at our national boundaries might even be a factor of ten less than Palanquin. Cabriolet is, thus, a key experiment. If it works as expected, it should permit proceeding with the following higher yield cratering experiments.

B. Schooner

Project Schooner is defined as a high-yield, point-charge experiment in hard rock. A site was tentatively identified for this experiment in Idaho before the Test Ban Treaty became effective. Data from this experiment would complement data from Project Sedan which, as you know, was a 100 kiloton point-charge detonation in alluvium at our Nevada Test Site. You are aware of the need for technical information from Schooner in order to extend to higher yields the theory of cratering in hard rock in view of the apparent predominance of harder rock types along the sea level canal routes, especially through the continental divide areas for which megaton size explosions will be needed. Equally important to you, of course, is the engineering information to be obtained after the shot on such matters as slope stability. Currently, we are in a position where the preliminary designs for canals are based on extrapolations from a one-half kiloton nuclear explosion and similar work to the several megaton explosions needed for the highest elevations along the canal routes.

C. Buggy

Project Buggy is defined as the simultaneous detonation of a row of low yield nuclear explosives in hard rock under level terrain. You are aware that no nuclear row charge experiment has ever been carried out and that we are extrapolating from very low yield, high explosive experiments in hard rock and alluvium to the very large yield nuclear row charges needed for a sea level canal. The technical and engineering information to be obtained from Buggy is similar to that to be obtained from Schooner. But, in this area, since there is a larger extrapolation in theory and in experimental data, there is an even greater need for the experiment. Also, there are many practical problems which we need experience in solving, such as the simultaneous firing of the large number of nuclear explosives.

D. Galley

Project Galley is defined as a row of higher yield nuclear explosions, detonated simultaneously, in uneven terrain and possibly heterogeneous media. Galley represents the logical extension of the basic Buggy experiment into the yield range from which extrapolations to a canal type excavation can be made. It is also a more sophisticated experiment using different yield explosives at different depths of burial to approximate the conditions under which nuclear excavation would actually be used in digging a sea level canal.

E. Other Experiments

We have also proposed, in the past, that a demonstration project be carried out using the basic technology evolved in the foregoing experiments. However, the foregoing four experiments are those needed for a specific determination of feasibility of the use of nuclear excavation for the construction of a sea level canal. Ideally, there would be several experimental objectives to a demonstration project as well as providing a demonstration that nuclear excavation actually works for practical projects. Such a project should be carried out in cooperation with another party, either industry or government, which plans to use the excavation for an engineering purpose.

In relation to the canal situation, we would strongly urge that such a demonstration project be carried out to support any decision by this Government to use nuclear excavation for construction of a sea level canal. If the project were in a foreign country it would probably serve this purpose even better. In this connection, the Australian Government has expressed some interest in a project of this type to construct an entrance channel and harbor in the barren coast line of northwest Australia. In this country a project, called Carryall, was studied in cooperation with the California Highway Department and the Santa Fe Railroad. It would have involved excavation of a railroad and highway pass in the Mojave Desert area of southern California, and would technically be an ideal extension of the Galley experiment into a yield range which would be directly useful in planning the actual construction of a sea level canal.

III. Progress in Reducing the Amount of Radioactivity Involved in Cratering

[redacted] such as the one to be used in Cabriolet, [redacted] In addition to the fission product radioactivity, radioactivity is induced in device structural materials, and to some extent the surrounding earth [redacted] In the Cabriolet design, it is expected that these induced activities will be on the order of [redacted]

[redacted]

Taking all these factors into consideration, plus the mixing and filtering effect of the overlying earth, we expect that the maximum concentration, based on Palanquin results, of radioactivity from Cabriolet in the air masses into which it would be introduced would be less than 10 picocuries per cubic meter of air after 50 hours. This concentration of radioactivity does not approach being a health hazard. In fact, it is not customary to analyze routinely samples which contain levels of radioactivity below 10 picocuries per cubic meter of air, since they are within the range of normal day-to-day variation. Furthermore, if the mixing and filtering effects of the overlying earth work on the escape of radioactivity as they did in the Danny Boy experiment, instead of the atypical Palanquin experiment, the concentrations of radioactivity after 50 hours would be about 1.5 picocuries of radioactivity.

This progress in reducing the amount of radioactivity represents a substantial technical achievement, the importance of which is not generally recognized. But, it is sufficient to enable us to proceed with a great deal of confidence in designing nuclear cratering experiments so that they do not pose undue risk of creating health hazards for the public.

In addition to these improvements, we are hopeful that the entrapment of radioactive debris underground can be enhanced by directing it down an extension of the emplacement hole which would be open for several hundred feet below the device. We believe we learned enough about this technique from the Palanquin experiment to test a basic improvement in the technique on the Cabriolet experiment. This technique offers the prospect of a further substantial decrease in the concentrations of radioactivity per cubic meter of air after 50 hours. It would be reasonable to assume that a reduction by a factor of ten is possible in which case the levels from Cabriolet would be 0.2 picocuries.

But, even without this technique, if Cabriolet confirms our expectations, we will be in a position to proceed with the cratering experiments outlined above and cause no more than 1.5 picocuries of the type of radioactivity collected by routine monitoring networks to be present per explosive per cubic meter of air after 50 hours. This means that even in the case of a high yield explosion like Schooner, there would be no more than about 1.5 picocuries of filterable radioactivity per cubic meter of air after 50 hours. In an experiment like Buggy, the concentrations in air masses after 50 hours would be the same, times the number of explosives. Thus, it would be possible to do Buggy using 7 explosives and cause no more than about 10 picocuries of radioactivity to be present under the same conditions. If the down-hole technique works, there might be only between 1 and 2 picocuries per cubic meter of air after 50 hours from Buggy.

IV. Technical Status and Program Capability

As indicated above in discussing the information to be obtained from each experiment, we are generally in the same technical position in

[redacted]

nuclear excavation that we have been in since the summer of 1962. Since that time, a thorough review of all the available information bearing on the nuclear excavation of a sea level canal has been made in the course of preparing the 1964 Isthmian Canal Studies. We believe that it is feasible to carry out such large scale nuclear excavation, but the fact is we do not know this. There are major technical uncertainties, as explained above, in the kind of craters to be left by large nuclear cratering explosions. And, there are major engineering uncertainties about the use of these craters for an engineering purpose.

Based upon past experience in development programs and advice from the best qualified technical and engineering experts who have reviewed the program in some detail, we believe the uncertainties to be investigated in the above nuclear cratering experiments are within the range of our past successful experience.

But, after careful scrutiny of this basic development program since early 1962, we believe this program of experiments is the minimum needed to determine the feasibility of nuclear excavation of a sea level canal; or, for that matter, other large-scale projects.

This experimental program can be carried out within the existing technical capability of the AEC without adversely affecting our other programs. We have the technical and field support capability to carry

[redacted]

out all of these experiments before June 30, 1968. And, depending upon the success we achieve with each experiment, it might also be possible to begin on an appropriate demonstration project, which if you recommend nuclear excavation of a sea level canal, might be a most desirable course of action.

At the present time, our budgetary situation is such that funds can be requested in an orderly fashion, within the usual budget cycle, to carry out the above projects. We have funds in FY 1966 to carry out Project Cabriolet. We have proposed in our FY 1967 budget request, which is now under consideration, that funds be included in the President's budget for Projects Schooner and Buggy and to make preliminary site preparations for Project Galley. However, we are currently at the stage in the budget review process where if funds are not included in the FY 1967 budget, supplemental appropriations or other funds would be necessary to maintain the schedule. Obviously, the budget has not been developed for FY 1968; but, if sufficient funds are provided in FY 1967, it will be possible to request funds in FY 1968 to execute Project Galley and possibly, if it appears justified, to initiate a demonstration project.

Beyond requesting funds in the President's budget, we must also face the fact that Congress is reluctant to authorize and appropriate funds for cratering experiments unless there is some indication that we actually intend to do them.

V. Effect of Test Ban Treaty

Mr. Palfrey explained at your July meeting the procedures used within the Government to obtain approval under the Test Ban Treaty for experiments

[redacted]

which might violate or be regarded as violating the terms of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, Outer Space, and Under Water. He pointed out that slight differences of interpretation of the relevant treaty language, prohibiting underground nuclear explosions "if such [an] explosion causes radioactive debris to be present outside the territorial limits of the state under whose jurisdiction or control such explosion is conducted", have a major effect on the kind of experiment we can carry out. At that meeting, in reviewing our general situation, we did not discuss in detail all of the technical issues which get involved in trying to apply the relevant treaty language in judging experiments. And, since the review is a comprehensive one, taking into account political risks, technical issues, and legal interpretations of the treaty language, as well as the need for the experiment from a national point of view; the question of slight differences of interpretation may not actually be too important. But, each of the agencies involved in the review undoubtedly have a different point of view based, in part, on a slightly different interpretation of the Treaty and our obligations under it. Clearly, it is important that technicalities not prevent us from taking action which otherwise appears necessary and desirable.

With this introduction, I would like to outline for you some of the ways in which the relevant treaty language may be interpreted.

A. Detectable

Testimony given by Administration witnesses before the Senate Foreign Relations Committee in behalf of ratification of the Test Ban Treaty frequently defines the Treaty language in question as prohibiting

[redacted]

"detectable" amounts of radioactive debris from being present outside territorial boundaries. Thus, there is some legislative history supporting this interpretation. However, applying this criterion today is inconsistent with other equally valid testimony stating that cratering experiments can be carried out under the Treaty. The Senate Foreign Relations Committee Report indicates their understanding that such experiments will be carried out. In any event, the threshold of detectability for radioactivity varies so much with background levels of radioactivity, meteorological conditions, sophistication of detecting equipment used, skill of detection, and level of effort employed, that this interpretation is both severely limiting and controversial. As Mr. Palfrey made clear, this interpretation has not been adopted by the Administration and, in fact, no uniform interpretation is employed by the Review Committee. From the standpoint of political risk or propaganda value, the question undoubtedly turns less on whether the debris is present in detectable amounts than it does on whether the debris is actually detected outside the country and whether that fact becomes known. It seems impossible to carry out cratering experiments in our open society without announcing this fact. Even if it were, our responsibility to protect the public from hazards results in activities which make the escape of radioactivity to the atmosphere known. In this same vein, it is of course true that even if debris is not detected outside the country, a propaganda opportunity is created by a cratering experiment. But, the same is even true of a reactor experiment we have carried out.

[redacted]

B. Not Present

This interpretation is based on the legal concept of using a "rule of reason" to define otherwise imprecise provisions of law. In this case, the concept is derived from the wording "to be present" in the Test Ban Treaty, and takes account of the fact that all recognized radiation protection guides, including those of the USSR, define as "not present" concentrations of a radionuclide below some level. The regulations governing maximum permissible concentrations are set low enough that it is judged such concentrations do not present a health hazard. The regulations therefore recognize that radioactivity which is some small fraction of the maximum permissible concentration represents a level of radioactivity so low that it is not necessary to try to monitor or control it. For all practical and health purposes, it is "not present." In the case of the USSR, where the concept is applied to waste disposal matters, it apparently really means that when the radioactivity concentrations are so low, it is not worth worrying about and for all practical purposes, water or air containing such low levels of radioactivity are not considered to be radioactive. (It should be borne in mind here that most water and air naturally contain some radioactivity.)

A precedent also exists for using this concept in interpreting an international treaty since it is used to control the release of effluent by the nuclear reactor at McMurdo Sound in the Antarctica.

[redacted]

This concept was first proposed in the spring of 1964 and was incorporated in the Department of State report to the White House. Subsequently, the Review Committee concurred in the desirability of continuing the study of this concept.

Since that time, the Atomic Energy Commission has pursued some of the detailed calculations necessary to establish the "not present" limit using the definition of "not present" in the U. S. Regulations (10 CFR 20). Based upon the actual mixture of radionuclides released in the Palanquin experiment last spring, the USSR event of January 15, 1965, which deposited radioactivity in easily measurable quantities in Japan, and the prediction for Cabriolet, the following "not present" limits for the radioactivity from these events has been calculated using the radiation standards suggested by the International Atomic Energy Agency, the U. S. and the USSR. The U. S. regulations have been developed on a slightly different technical basis than the IAEA, and the USSR regulations are meant to be applied somehwat differently than the IAEA and U. S.

RADIOACTIVITY FROM NUCLEAR EXCAVATION

Concentrations of Radioactivity Considered "Not Present" Under Various Regulations

	Picocuries of Radioactivity* Per Cubic Meter of Air (pc/m^3) at 50 Hours		
Source of Definition	USSR Event	Palanquin	Cabriolet
1. USSR Regulations	270	113	340
2. U. S. Regulations	460	125	610
3. IAEA Regulations	910	365	1,090
Actual or Estimated Concentrations	6,000	60	0.2 - 7

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*Gross Beta Activity Collected by Air-Filter Units

[redacted]

Of course, when the radioactivity from the USSR event was measured over Japan after 120 hours, the levels were only 188 picocuries which may account for their statement that the event was fired under conditions that preclude it being present.

Although the "not present" levels of radioactivity would be easily measurable by routine health monitoring networks, it should be borne in mind that such levels really represent extraordinarily small physical quantities and that in every day practice in countries around the world, similar levels of radioactivity are released to the environment. Regardless of whether it would be practical from a political and propaganda point of view to use such a standard, it is being borne in mind as a possible way in which to answer charges made by others about any of our nuclear activities.

C. Evolutionary Interpretations

This might fairly be the name given to the situation we are in as we pursue the case-by-case approval of each nuclear cratering experiment. So far, two nuclear cratering experiments have been approved by the Review Committee. In neither case did the concentration of radioactivity crossing our borders exceed one picocurie per cubic meter of air. As indicated above, with conservative assumptions, we would expect the levels from Cabriolet to be no more than 10 picocuries of radioactivity per cubic meter of air after 50 hours. More likely, they will be no more than 2 picocuries. If the air masses containing the radioactivity stay within our territorial boundaries longer than 50 hours, the levels would be even less. However, 50 hours has been chosen because meteorological experts tell us they can predict with reasonable confidence, air mass trajectories

[redacted]

that will remain in territorial boundaries for that length of time.

Another factor which feeds into the evolutionary interpretation is the type of experiments permitted by other countries which have signed the Treaty. Such experience provides an indication of their interpretations. In this connection, the Soviet event clearly caused extremely high levels to cross their nearest border, with Outer Mongolia, about 300 miles away. A reasonable estimate would place the concentration of radioactivity at that location in the range of a few million picocuries per cubic meter of air. It remains a moot point, of course, whether the Russians deliberately approved the experiment with full knowledge that this amount of radioactivity would be released. There is some evidence to suggest that they did. If so, the U. S. would certainly be justified in taking a somewhat less restrictive attitude toward the approval of its own tests.

In connection with the approval of experiments, it should be noted that the Secretary of State assured the Congress during consideration of the Nuclear Test Ban Treaty that if another party should interpret the Treaty more broadly, the U. S. would consider itself free to extend its underground testing program to the limits observed by the other parties.

Beyond the question of interpretation, of course, there remains a clear desire on the part of the U. S. to proceed with tests necessary in its national interest so long as there is no conflict with a higher national interest. In this area, I believe our national interest would dictate that we not fall behind the USSR in developing nuclear excavation techniques.

[redacted]

VI. International Cooperation

Since the Senate debate on ratification of the Test Ban Treaty, it has been recognized that the Treaty would probably prevent the use of nuclear excavation for a sea level canal. It was explained to the Congress that if a sea level canal or other projects became desirable, it would be possible to amend the Treaty to permit the project. Later, in January, 1964, in connection with the riots in Panama and during consideration of the need for a sea level canal, this fact received careful consideration. Two important conclusions have emerged from this consideration: (1) If the Government is to keep its obligations under the Treaty, an amendment to the Treaty, or an arrangement under it, would be necessary to permit nuclear excavation of a sea level canal. At the same time, it is apparent that until the nuclear excavation program is completed, there will be no actual projects requiring an amendment to the Treaty. (2) The prospects at this time for obtaining an amendment to, or an agreement under, the treaty are not good and depend largely on the attitude of the Soviet Union as one of the three original signatories to the Treaty. As the result of this latter conclusion, the Department of State proposed that a program of Soviet and international participation and cooperation in the nuclear excavation development program be devised and carried out. It would be expected that participation in and cooperation during the developmental and experimental phases of the program would create sufficient understanding of and interest in nuclear excavation so that an amendment or an arrangement for a needed project could be obtained. So far, it has not been possible to proceed with the

[redacted]

implementation of this program. Most recently, it has been concluded that an approach to the Soviet Union at this time would be fruitless in view of the current state of our relations in other areas and might jeopardize our chances at a later, more favorable time.

Perhaps on a case-by-case basis, we should begin to intensify already existing contacts with other countries, such as Australia, Peru, and the United Arab Republic. India represents a slightly different problem. But, it, too, is among the countries who are interested in Plowshare technology.

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As Commissioner Palfrey mentioned at your July meeting, the Atomic Energy Commission has, after careful consideration, concluded that Plowshare is not fundamentally incompatible with other foreign policy initiatives to prevent the spread of nuclear weapons to other countries or to obtain a comprehensive test ban treaty. Policies and arrangements can be worked out in both of these areas so that Plowshare should not frustrate our foreign policy objectives. In the case of proliferation, appropriate policies in the Plowshare area would even serve these objectives by removing a reason or an excuse for another country undertaking an independent explosives development program. First, we believe a definite U. S. policy should be adopted to make Plowshare technology available to other nations, including the service of detonating U. S. explosives at reasonable costs, to obviate any need for them to pursue an independent program. Providing this service, with the explosives under U. S. control, would not provide any technology or materials useful in designing nuclear explosives. Second, we should make it clear that the U. S. would regard any nuclear explosive development by another nation as being for weapon purposes.

[redacted]

VII. Conclusions

The foregoing is a comprehensive and somewhat detailed picture of the situation as it stands today. I think it is clear that the situation is exceedingly complex and weaves together many technical, political, legal, and even psychological threads. For one reason or another, since 1958, nuclear excavation has not progressed in the orderly, straight-forward manner we would like to use in pursuing technical development programs.

I understand you are interested in knowing what the chances are that we will be able to proceed with our experimental program and obtain the information you need to make your determinations. For this reason, let me review what we are doing and what can be done to improve those chances.

First, we will continue to propose nuclear cratering experiments for review in the expectation that they will be approved and that there will be some evolution in the standards of appraisal used in the review as well as some technical progress. If so, we will be able to carry out the nuclear excavation development program. The schedule would then depend mainly upon our ability to secure funds for it.

Second, as we follow this procedure, we can use the occasion of nuclear excavation experiments to determine whether more flexible limits are acceptable to other nations. There is growing reason to believe from intelligence and other information that the Soviet Union may have dropped its former political hostility to plowshare technology and may even be embarked on a development program not unlike the one we are proposing. It is, of course, even possible that they have been doing so for a number of years, taking advantage of their closed society to carry out the program clandestinely.

Third, even if it is not timely to approach the Soviet Union directly on cooperation in Plowshare, we can intensify our efforts to cooperate with other nations in plowshare technology. In doing so, there are, even, many areas other than nuclear excavation which are completely permissible under the Test Ban Treaty, such as stimulation of natural gas or petroleum production, which can be pursued to our advantage.

Fourth, in carrying out nuclear cratering experiments beyond Cabriolet, we believe that the U. S. can effectively counter any propaganda in connection with nuclear cratering experiments by inviting interested nations to observe the experiments first-hand so that they will understand what we are doing and why we do not believe it is a violation of the Test Ban Treaty.

Fifth, it would be possible technically to carry out all the experiments I have outlined without violating a "not present" standard. Even if we do not use this standard to approve experiments, the "not present" interpretation provides us a basis to meet challenges from the USSR that we have violated the Nuclear Test Ban Treaty.

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MEMORANDUM FOR THE PRESIDENT

DECLASSIFIED
Authority STATE letter SEP 22 1978
By ip, NARS, Date 6-4-79

SUBJECT: Sea Level Canal

The building of a sea level canal at a new route has been under active study by the Panama Canal Company, the U. S. Army Corps of Engineers and the Atomic Energy Commission. This memorandum considers factors bearing on the desirability and feasibility of constructing such a canal. It does not consider actions which might be taken to improve U. S.-Panama relations while we are operating the present canal.

I. The Need for a Sea Level Canal

A. Economic Need

A current study, undertaken at President Kennedy's direction to be completed February 15, 1964, indicates that by the end of the century traffic through the Panama Canal will have grown from the current rate of 12,000 ships a year to about 19,000; but that the Canal under optimum conditions will be able to accommodate the traffic until that level is reached. As the annual volume of traffic approaches capacity, however, the normal daily variations in the number of ships arriving will result in substantial delays to shipping and a backlogging of ships awaiting transit. By the year 2000, the limitations imposed by the capacity of the canal will result in substantial inconvenience to world shipping and particularly to the U. S. (64% of the tonnage which passed through the canal in 1963 originated in or was destined for U. S. ports).

Even now the dimensions of the locks preclude the use of the canal by 50 existing commercial ships (ore carriers, tankers and Queen class passenger liners) and 24 U. S. naval vessels (15 attack carriers and 9 ASW carriers). An additional 556 commercial vessels which can transit the locks in ballast cannot transit it when fully laden.

It follows that while a new sea level canal would aid the world's commerce, its construction in the next 25 years could probably not be justified on the sole ground of inadequate service. Thereafter, the inadequacy of the present canal will undoubtedly grow to be a real burden on commerce.

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B. Political Need

We have not yet been able to devise a completely satisfactory United States-Panamanian relationship involving U. S. operation of the present lock canal for the following reasons:

1. U. S. Population

The operation and security of a lock canal involves skilled and loyal technicians, a tight organization and good management. Hence, in the near future in Panama a substantial complement of American citizens is required. Their presence in the Canal Zone means a large American enclave in a small foreign country. The juxtaposition of Panamanian slums and neat, affluent American communities will always tend to breed trouble.

If a sea level canal is built, no complicated operating problems will be presented. Even assuming U. S. operation of a new canal, the U. S. supervisory force would not exceed 100 men as contrasted with the 4,000 U. S. citizens (supervisory and support) currently employed by the canal enterprise in the Zone.

2. Land

The extreme vulnerability of the present canal to sabotage (dynamite at Gatun Dam would close the canal for two years) requires a buffer area - much of it unused - if the canal is to be protected. With a sea level canal, vulnerability to major sabotage would be eliminated and, therefore, no buffer area would be required.

3. Treaty Issue

The current treaty raises the problem of sovereignty and grants rights to the U. S. "in perpetuity". Changes in the treaty which would satisfy Panama would be difficult to sell to a substantial segment of the U. S. public.

In the case of a sea level canal where no sizeable U. S. community is required and no significant security problem exists, sovereignty should not be an issue. Furthermore, the rights need not be "in perpetuity" but rather for the period of years required to amortize the investment. Provision would have to be made to assure that, once the cost of the canal had been amortized the canal would be operated efficiently, and that ships of all nations could use it at fair rates.

Accordingly, the prospect of a sea level canal gives promise of providing a way out of the difficult problems with Panama which we now face. It provides the possibility of an arrangement with Panama, satisfactory to both countries and without adverse international implications, which could safely guarantee inter-oceanic passage to world commerce indefinitely in the future.

If, on the other hand, a sea level canal could be constructed outside of Panama, the current problems with Panama should become manageable.

C. Strategic Need

1. Waterway

The JCS have stated that long-range military considerations will continue to make mobility of forces and materiel between the Atlantic and Pacific Oceans during cold, limited, or general war desirable. As previously stated, 24 U.S. carriers cannot transit the canal today. More important, the vulnerability of the present canal reduces its capability to meet U.S. strategic requirements in wartime. The Navy estimates that without the canal it would need additional ships and personnel to enable it to meet its responsibilities throughout the world. Additional studies will be necessary to ascertain the number of ships and personnel which may be needed.

2. Bases

The strategic importance of the Canal Zone is not based solely on the military value of the Canal as an inter-oceanic waterway. The military bases located there also play a vital role in hemispheric defense.

At these bases we maintain U.S. forces and supplies which may be required to counter subversion in Latin America. In addition, we maintain a permanent, well-protected headquarters for control of U.S. military and military assistance operations in Latin America; a tropical jungle site for research and development activities;

an extensive training complex for U. S. and Latin American personnel which includes one of the finest jungle training areas in the world, Fort Sherman; an excellent school for Latin American military personnel, Fort Gulick; and a base for world-wide communications which is favorably located from a technical (i. e., wave propagation) standpoint.

It should be pointed out, however, that the continued maintenance of these bases does not depend upon continued operation of the canal at the present site or maintenance of U. S. jurisdiction over the Zone. These bases contribute substantial indirect benefits to Panama and could probably be retained at their present sites under normal base rights arrangements.

D. Conclusion

Although economic, political and strategic considerations taken separately do not require the construction of a sea level canal in the near future, when they are linked together a strong case for such a canal is made.

II. The Choice Between Nuclear and Conventional Construction

A. Conventional Construction

A sea level canal could be built by conventional means. The cost of such a canal at the present site was estimated in 1960 to be $2,287,000,000, and the construction time to be 12 years. The resulting canal would be narrow and subject to being blocked by a scuttled ship.

Nevertheless, several considerations favor such a canal: (1) It would obviously be more efficient and far easier to operate than the present canal; (2) It would permit transit in 4 as against 8 hours; (3) If the canal were dug at the present site, Panamanian consent to it should be easily obtainable, in view of the enormous economic benefits to Panama from the expenditure locally of the major portion of the funds required for construction.

Construction of a sea level canal by conventional means at any of the other possible routes appears impracticable in view of the distances and elevations and, hence, costs involved, which are shown in the table below. These estimates, however, do not make allowance for any possible future improvement in conventional earth moving equipment.

Cost of Conventional Sea Level Canals

Site	Length (Miles)	Max. Elevation of Divide (Feet)	Cost of Construction (Estimated in 1947) (Millions)
Mexico (Tehuantepec)	125	810	$ 13,000*
Nicaragua (Greytown-Salinas Bay)	140	760	$ 4,100*
Panama (Sasardi-Morti)	46	1100	$ 5,132
Panama (Canal Zone)	46	590	$ 2,287**
Colombia (Atrato-Truando)	102	950	$ 5,261

B. Nuclear Construction

1. Feasibility

A canal dug by nuclear means would have a channel up to 250 feet deep and would be at least 1,000 feet wide (as against the 600 foot width of a conventional sea level canal in the Zone). Its course would be relatively straight. Tidal regulation structures would probably not be required, even though Pacific tides vary by 20 feet and Atlantic tides by 1-1/2 feet. This variation would, on occasion, cause currents in the channel up to 5 knots, not a severe problem.

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* 1947 estimate for lock canal only. No estimate has been made for sea level canal.

** 1960 estimate for sea level canal. 1947 and 1960 estimates were relatively close. A new canal at this site could, and necessarily, would be built with the present one in operation; a shut-down of only two weeks would be required [illegible] change-over time. The cost in time and money is, of course, substantially increased as a result of carrying on canal operations during construction.

The feasibility of excavating a sea level canal by nuclear means has been demonstrated by actual excavation experiments, although further work has to be done to develop this technology to the point where a canal project can be undertaken. The program to date has consisted of several hundred chemical explosive tests up to 500 tons and four nuclear cratering events, of which three were fired as military effects shots. One major Plowshare event at 100 kilotons, fired in Nevada in 1962, excavated a crater 1,200 feet in diameter and 320 feet in depth (see attached photographs). This explosion, which is of the magnitude of the small (but not the large) explosives that would be required to excavate the proposed canal, was conducted safely at the Nevada test site.

Extrapolations from the data developed in this program indicate that a sea level canal can be dug across the Sasardi-Morti route in Panama with about 300 nuclear explosives. The total yield required is about 200 megatons. The yield of the individual explosives would range from about 100 kilotons up to about 10 megatons. To excavate the canal, a number of devices would be simultaneously detonated in a row to produce a ditch. About 15 such rows of detonation would be required to complete the excavation for the Sasardi-Morti route. The total yield in any row of detonations would be determined by local conditions but would not exceed about 35 megatons.

2. Costs

Construction of a canal by nuclear means brings the cost down sharply and permits a choice of routes as the following table shows:

Site	Estimated (in 1960) Construction Cost (Millions)
Mexico (Tehuantepec)	$ 2,300
Nicaragua (Greytown-Salinas Bay)	$ 1,900
Panama (Sasardi-Morti)	$ 770
Colombia (Atrato-Truando)	$ 1,200

A map is attached showing the sites listed.

These costs cover site selection, engineering surveys and design, construction of roads and camps, production of nuclear devices (including nuclear materials), nuclear operations in the field, evacuation of local inhabitants during the detonation period, and such permanent facilities as navigational aid and flood control structures, but do not include treaty costs. The research and development cost, not included in the above, to perfect nuclear construction techniques is estimated to be about $75,000,000 for a four-year program, but would be incurred in substantial part for other purposes in the Plowshare program in any event.

3. Safety

The safety of nuclear excavation depends upon the control of the main potential hazards: radioactivity, air blast, and ground shock.

Radioactivity would be limited in two ways. First, explosives have been developed with the primary objective of minimizing it. The Atomic Energy Commission has made and is making substantial progress in this development and this program should continue. Second, deep burial of the explosives would trap a large percentage of the radioactivity underground. In addition, the prevailing winds from the northeast are essentially across the Isthmus and along the canal axis, so that the land area subject to fallout is minimized. It is believed that dilution and decay on land and in the ocean would reduce concentration to harmless levels in a short time.

Current plans are to conduct the nuclear detonations over a period of two to three years. In a jungle area it would not be practical to evacuate the inhabitants temporarily for each detonation. Therefore, current plans envisage working through the local government and tribal headmen, before any detonations begin, to resettle all the people from the land area where any radioactive fallout is likely to occur. This is a pie-shaped area 30-50 miles wide at the Caribbean end, upwind, and 100-150 miles wide at the Pacific end, downwind.

The evacuation plan would mean resettlement in adjacent frontier areas of approximately 25,000 people in the vicinity of the Sasardi-Morti Route (Panama), or an estimated 60,000 people in the vicinity of the Atrato-Truando Route (Colombia). The cost estimates include resettlement and village construction costs at the rate of $3,000 per person. These plans should assure that no person will be subjected to radioactivity in dangerous quantities.

From the above, it is obvious that evacuation and resettlement of local inhabitants presents some very substantial problems.

The probability of damage from air blast or ground shock beyond the evacuated area is small except for the large explosion for the Divide cut. High altitude winds will have to be measured at the time of the shots to assure that refraction of damaging blast waves from the largest explosion to distances as great as Panama City can be avoided.

4. Amortization of Costs

Because of the low operating costs, the construction cost of a sea level canal can be amortized in a reasonable period of time.

The present canal receives $60,000,000 in tolls annually. It has 14,000 employees and carries the expense of governing and maintaining the 550 square mile Zone. The fiscal 1963 operating profit of the current canal enterprise, including returns from the profitable auxiliary operations, but before payment of interest to the U. S. Government or annuity to Panama, was $12,800,000.

By contrast, a sea-level canal which earned $60,000,000 a year in tolls would require a labor force of no more than 800 men and there would be no Zone to maintain. At such a toll level, the operating profit before interest or annuity charges would be approximately $52,000,000 per year. As a result, a substantial amortization payment could be made annually even though the annuity to the host country were increased substantially above the current $1,900,000.

It should be pointed out that this rough analyses does not purport to compute any "readjustment" costs which might arise from moving the canal, or from the payment of military-base fees.

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In sum, a nuclear canal is feasible from a technical and economic standpoint and the substantial difference in costs and the wider choice of location weigh heavily in its favor. Its construction, however, involves serious domestic and international issues.

III. Problems Posed by a Nuclear Canal

A. Host Country Approval

1. Panama

It will be difficult to obtain Panamanian consent to the construction of a canal by nuclear means.

First, the use of nuclear devices presents an obvious problem. No matter how safe the device, some fallout is inevitable and there will undoubtedly be a widespread fear on the part of the uneducated, uninformed, and superstitious population, which could be exploited. The best counter to this fear would be the safe demonstration of nuclear excavation in U. S. territory. Projects of this type (Carryall in California and Tennessee, Tom Bigbee in Mississippi) are under consideration at the present time. It should be noted, however, that these projects present test ban treaty problems as subsequently discussed..

Second, termination of the present-canal operations would have a severe economic impact on Panama. Ten thousand Panamanians are employed in connection with the present Canal; the payroll has reached an annual level of $35,000,000. Panama City and Colon virtually depend for their existence on this labor force and on the business which the Canal itself produces. The current Canal operation, its contractors, and its U. S. employees and Canal Zone military activities spend an additional $50,000,000 in Panama.

On the other hand, if a new canal is built, the present Zone, except for military installations, would be returned to Panama, with obvious benefits to Panama. The hydroelectric potential of Gatun Lake (the second largest man-made lake in the world) with a normal water level 85 feet above sea level, is substantial. Plentiful electric power, the trained labor force, the Zone installations, and further U. S. aid could provide a start toward industrialization.

In addition, we would wish to preserve our military installations in Panama and certain necessary supporting facilities under a base rights arrangement. This would continue to provide an important return to the Panamanian government and substantial indirect benefits to Panama. It is estimated that these benefits would amount to $30,000,000 to $40,000,000 annually.

If Panama should reject a proposal to build a new canal in Panama, it would seem desirable to seek rights in another country. An option in another country could radically change our bargaining position in Panama for the better.

2. Other Countries

Proposed routes in Nicaragua, Mexico or Colombia are more than twice as long as the routes through Panama, but it is likely that rights for excavating a nuclear canal through these countries, excepting Mexico, would be more easily secured. It is true that fallout is feared everywhere and the problem of obtaining consent to the use of nuclear devices will always be difficult. On the other hand the economic benefit of a new canal to one of these countries would be far greater than in the case of Panama. Unlike Panama, they have no existing canal with dependent cities which will suffer if the canal is moved. Any benefits from a sea level canal would be a net gain for Colombia, Nicaragua or Mexico.

In this connection it is worth noting that Colombian officials have expressed their willingness to have U. S. teams survey the proposed Atrato-Truando route in their country.

B. Congressional Approval

The Congress has manifested little interest in a sea level canal prior to recent Panamanian riots. For example, HR 80, authorizing studies for a new or improved canal, was introduced at the beginning of the 88th Congress, but no hearings have been held on the bill by the House Merchant Marine Committee to date.

Furthermore, in the past a strong body of congressional opinion has firmly opposed any change in the status quo in Panama and has insisted upon the maintenance of U. S. rights "as if sovereign" in the present zone.

However, recent events have quickened interest in an alternative to the present canal. Senators Mansfield and Cotton have made proposals for the study of new routes and have received support from other members of Congress.

It is likely that the political, economic, and strategic considerations described earlier will stimulate in time the congressional support required to build a sea level canal.

C. Test Ban Treaty

Under the terms of the Test Ban Treaty, nuclear explosions are prohibited which cause "radioactive debris to be present outside the territorial limits of the State under whose jurisdiction or control such explosion is conducted." Little hope is held that nuclear excavation techniques can be developed which can excavate the canal without some detectable fallout occurring on international waters outside of Panama or Colombia.

A treaty-amendment requires approval of a majority of the participating nations, including all the original parties (U. S., U. K., and Russia). Obtaining such amendment -- even if limited to one isolated project such as a canal -- would be difficult for some years. However, we could undertake at the proper time to obtain such amendment by pointing out the benefits to the Western Hemisphere, and possibly to the Soviets of similar projects. We must also provide proper safeguards to ensure that neither side gains from such excavation programs any information on weapons design or effects which could not be gotten as easily or more easily by underground tests.

Should Russia insist on examining the internal design of the device, a difficult problem would be presented. It is the view of the AEC that our advanced devices by which we have reduced the fission products from large yields reveal our most advanced nuclear technology and therefore must not be exhibited. Older devices, which could be exhibited to the Russians, cannot be used because they produce excessive fallout.

An alternative is to allow Soviet and neutral observers to note that in these excavations there are no atmospheric effects of the kind which would be useful in weapons application (electromagnetic and nuclear radiation pulses of the sort which make blackout, etc.) and no equipment to measure them. The groundwork could be laid for such a procedure by international attendance at earlier nuclear excavations in the U. S. We may thus be able to establish the required assurance, which we also would need in the case of Soviet activities, that a general amendment to authorize excavations causing only minimal radioactivity beyond national boundaries would not be used for military development purposes. This would require close inspection of the outside of the explosive, its placement, and the surrounding area, which the Soviets would be much less willing than we to allow, posing a problem of negotiability. With respect to weapons development, an externally inspected cratering shot, with measurements on the bomb itself barred, would be much less useful than an instrumented one at twice the depth (hence fully contained and legal under the treaty) so that there is no reason to use excavating shots for that purpose. If the several multi-megaton explosions presently planned for use at the highest elevation on the canal route raise a question about whether the yields are ones which could be adequately contained, a substitution of a number of 1-2 megaton explosives simultaneously detonated might be made at an acceptable extra cost.

Finally, some question has been raised as to whether the nuclear excavation technique can be completely established in the U. S. without an amendment of the Test Ban Treaty. The treaty will not impede the device development which can be done entirely underground. Though more cratering tests must be carried out in order to establish final feasibility, the ones involving larger amounts of radioactive debris may not need to be done for several years.

The DOD General Counsel advises that in terms of the negotiating history of the Treaty, it is at least arguable that the early cratering experiments to be done in the U. S. are legal. Because the devices are in fact buried the explosions will be nearly contained, and the size of the explosion is so small and the distance to a border so great that fallout outside the U. S. will be practically undetectable. The argument for legality will be more difficult in the case of the canal since explosions will be larger and distances to the borders smaller.

Under existing procedures, decisions on nuclear test explosions which might raise questions under the Treaty are made on an ad hoc basis by the President, after full analysis by the sponsoring agency, reviewed by a committee of interested agencies chaired by Mr. McGeorge Bundy. This committee has not established a precise definition for the Treaty terms "radioactive debris to be present." Some of the needed cratering shots could probably be approved by this committee with little if any change in its existing standards of appraisal.

IV. Necessary Actions Leading Toward the Construction of a Sea Level Canal

A. Obtain passage of House Bill H. R. 80 (or a similar Senate Bill 2428) authorizing site surveys, and obtain the necessary appropriations ($17,000,000 for two routes).

B. Decide where surveys are to be made, and obtain right to conduct them.

C. Finish mapping Panamanian and Colombian routes. Mexican and Nicaraguan maps have been completed.

D. Complete the analysis of effect of Test Ban Treaty on nuclear excavation.

E. Conduct surveys, to include weather observations and drilling to ascertain the sub-surface geology so that test explosions to determine cratering effects can be made elsewhere in similar conditions (3 to 4 years).

F. Complete Plowshare tests. The program involves further improvement of special explosives, their production, and continued development of explosive cratering technology, including a demonstration project in the U. S. The program is now under way and could be completed within about four years.

G. Decide where and how canal is to be built.

H. Negotiate treaty or treaties when desirable.

I. Obtain ratification of the treaty in the Senate and congressional authorization and appropriation for construction of a new canal.

J. Excavate the canal and build the necessary traffic control installations (6 years for Panama, 9 years in Colombia).

The total time from date of decision is from 12 to 18 years.